CAMPBELL BIOLOGY

CONCEPTS & CONNECTIONS

TENTH EDITION

TAYLOR
SIMON
DICKEY
HOGAN

Brief Contents

CAMPBELL BIOLOGY

CONCEPTS & CONNECTIONS

TENTH EDITION

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Library of Congress Control Number: 2019914541

ScoutAutomatedPrintCode

Pearson

ISBN 10: 0-135-26916-4; ISBN 13: 978-0-135-26916-9 (Student edition)
ISBN 10: 0-136-62348-4; ISBN 13: 978-0-136-62348-9 (Instructor Review Copy)

www.pearson.com

About the Authors

Martha R. Taylor has been teaching biology for more than 35 years. She earned her B.A. in biology from Gettysburg College and her M.S. and Ph.D. in science education from Cornell University. At Cornell, Dr. Taylor has served as assistant director of the Office of Instructional Support and has taught introductory biology for both majors and nonmajors. Most recently, she was a lecturer in the Learning Strategies Center, teaching supplemental biology courses. Her experience working with students in classrooms, in laboratories, and with tutorials has increased her commitment to helping students create their own knowledge of and appreciation for biology. She was the author of the *Student Study Guide* for ten editions of *Campbell Biology*.

Eric J. Simon is a professor in the Department of Biology and Health Science at New England College in Henniker, New Hampshire. He teaches introductory biology to science majors and nonscience majors, as well as upper-level courses in tropical marine biology and careers in science. Dr. Simon received a B.A. in biology and computer science and an M.A. in biology from Wesleyan University, and a Ph.D. in biochemistry from Harvard University. His research focuses on innovative ways to use technology to improve teaching and learning in the science classroom. Dr. Simon also leads numerous international student field research trips and is a Scientific Advisor to the Elephant Conservation Center in Sayaboury, Laos. Dr. Simon is the lead author of the introductory nonmajors biology textbooks *Campbell Essential Biology,* Seventh Edition, and *Campbell Essential Biology with Physiology,* Sixth Edition, and the author of the introductory biology textbook *Biology: The Core,* Third Edition.

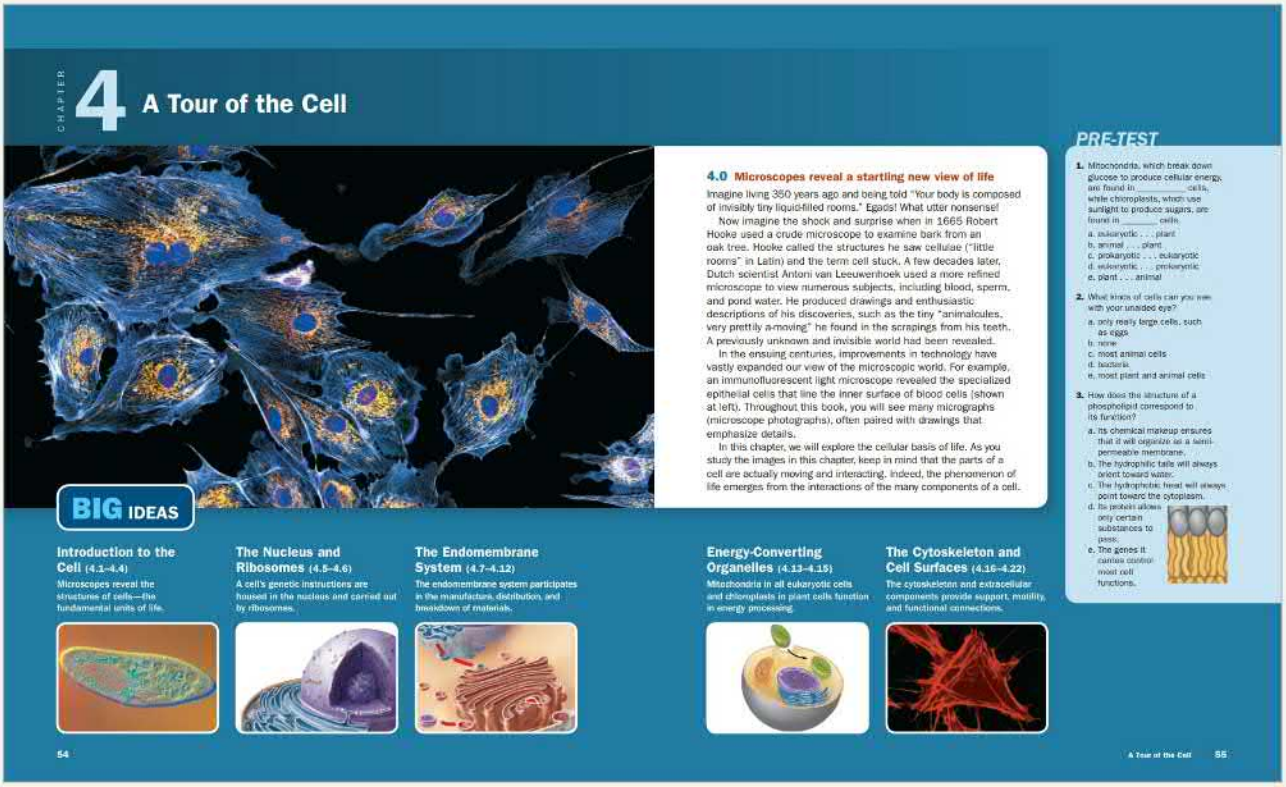
Jean L. Dickey is Professor Emerita of Biological Sciences at Clemson University (Clemson, South Carolina). After receiving her B.S. in biology from Kent State University, she went on to earn a Ph.D. in ecology and evolution from Purdue University. In 1984, Dr. Dickey joined the faculty at Clemson, where she devoted her career to teaching biology to nonscience majors in a variety of courses. In addition to creating content-based instructional materials, she developed many activities to engage lecture and laboratory students in discussion, critical thinking, and writing, and implemented an investigative laboratory curriculum in general biology. Dr. Dickey is author of *Laboratory Investigations for Biology*, Second Edition, and coauthor of *Campbell Essential Biology*, Seventh Edition, and *Campbell Essential Biology with Physiology*, Sixth Edition.

Kelly Hogan is a faculty member in the Department of Biology at the University of North Carolina at Chapel Hill, teaching introductory biology and genetics. Dr. Hogan teaches hundreds of students at a time, using active-learning methods that incorporate educational technologies both inside and outside of the classroom. She received her B.S. in biology at the College of New Jersey and her Ph.D. in pathology at the University of North Carolina, Chapel Hill. Her research interests focus on how large classes can be more inclusive through evidence-based teaching methods and technology. As the Director of Instructional Innovation at UNC, she encourages experienced faculty to take advantage of new professional development opportunities and inspires the next generation of innovative faculty. Dr. Hogan is the author of *Stem Cells and Cloning,* Second Edition, and co-author on *Campbell Essential Biology with Physiology*, Sixth Edition.

Neil A. Campbell (1946–2004) combined the inquiring nature of a research scientist with the soul of a caring teacher. Over his 30 years of teaching introductory biology to both science majors and nonscience majors, many thousands of students had the opportunity to learn from him and be stimulated by his enthusiasm for the study of life. While he is greatly missed by his many friends in the biology community, his coauthors remain inspired by his visionary dedication to education and are committed to searching for ever better ways to engage students in the wonders of biology.

Open up the World of Biology

NEW! Chapter Openers invite students into each chapter with a brief preview of what will be covered to help them learn and retain information. Written in a casual style, the Chapter Openers feature three pre-test questions that follow Bloom's taxonomy and link to interactive versions in the Pearson eText.



CHAPTER 4 A Tour of the Cell

4.0 Microscopes reveal a startling new view of life

Imagine living 350 years ago and being told "Your body is composed of invisibly tiny liquid-filled rooms." Egads! What utter nonsense!

Now imagine the shock and surprise when in 1665 Robert Hooke used a crude microscope to examine bark from an oak tree. Hooke called the structures he saw cellulae ("little rooms" in Latin) and the term cell stuck. A few decades later, Dutch scientist Antoni van Leeuwenhoek used a more refined microscope to view numerous subjects, including blood, sperm, and pond water. He produced drawings and enthusiastic descriptions of his discoveries, such as the tiny "animalcules, very prettily a-moving" he found in the scrapings from his teeth. A previously unknown and invisible world had been revealed.

In the ensuing centuries, improvements in technology have vastly expanded our view of the microscopic world. For example, an immunofluorescent light microscope revealed the specialized epithelial cells that line the inner surface of blood cells (shown at left). Throughout this book, you will see many micrographs (microscope photographs), often paired with drawings that emphasize details.

In this chapter, we will explore the cellular basis of life. As you study the images in this chapter, keep in mind that the parts of a cell are actually moving and interacting. Indeed, the phenomenon of life emerges from the interactions of the many components of a cell.

PRE-TEST

1. Mitochondria, which break down glucose to produce cellular energy, are found in _____ cells, while chloroplasts, which use sunlight to produce sugars, are found in _____ cells.
   a. eukaryotic . . . plant
   b. animal . . . plant
   c. prokaryotic . . . eukaryotic
   d. eukaryotic . . . prokaryotic
   e. plant . . . animal
2. What kinds of cells can you see with your unaided eye?
   a. only really large cells, such as eggs
   b. none
   c. most animal cells
   d. bacteria
   e. most plant and animal cells
3. How does the structure of a phospholipid correspond to its function?
   a. Its chemical makeup ensures that it will organize as a semi-permeable membrane.
   b. The hydrophilic tails will always orient toward water.
   c. The hydrophobic head will always point toward the cytoplasm.
   d. Its protein allows only certain substances to pass.
   e. The genes it carries control most cell functions.

BIG IDEAS

Introduction to the Cell (4.1–4.4)
Microscopes reveal the structures of cells—the fundamental units of life.

The Nucleus and Ribosomes (4.5–4.6)
A cell's genetic instructions are housed in the nucleus and carried out by ribosomes.

The Endomembrane System (4.7–4.12)
The endomembrane system participates in the manufacture, distribution, and breakdown of materials.

Energy-Converting Organelles (4.13–4.15)
Mitochondria in all eukaryotic cells and chloroplasts in plant cells function in energy processing.

The Cytoskeleton and Cell Surfaces (4.16–4.22)
The cytoskeleton and extracellular components provide support, motility, and functional connections.

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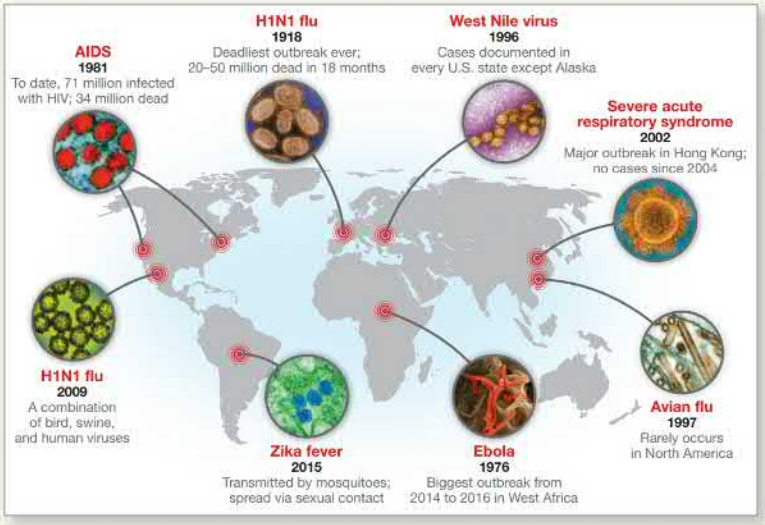
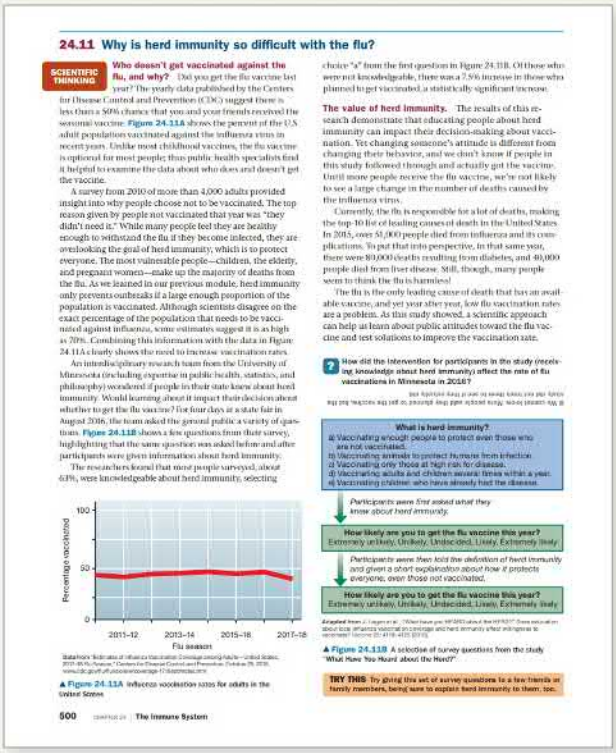
A Tour of the Cell 55

Build Science Literacy Skills



Visualizing the Data Figures are eye-catching infographics designed to provide students with a fresh approach to understanding concepts illustrated by quantitative information.

Scientific Thinking modules explore how scientists use the process of science and discovery. End-of-module questions prompt students to think critically.



24.11 Why is herd immunity so difficult with the flu?

SCIENTIFIC THINKING

Who doesn't get vaccinated against the flu, and why? Did you get the flu vaccine last year? The yearly data published by the Centers for Disease Control and Prevention (CDC) suggest there is less than a 50% chance that you and your friends received the seasonal vaccine. Figure 24.11A shows the percent of the U.S. adult population vaccinated against the influenza virus in recent years. Unlike most childhood vaccines, the flu vaccine is optional for most people; thus public health specialists find it helpful to examine the data about who does and doesn't get the vaccine.

A survey from 2010 of more than 4,000 adults provided insight into why people choose not to be vaccinated. The top reason given by people not vaccinated that year was "they didn't need it." While many people feel they are healthy enough to withstand the flu if they become infected, they are overlooking the goal of herd immunity, which is to protect everyone. The most vulnerable people—children, the elderly, and pregnant women—make up the majority of deaths from the flu. As we learned in our previous module, herd immunity only prevents outbreaks if a large enough proportion of the population is vaccinated. Although scientists disagree on the exact percentage of the population that needs to be vaccinated against influenza, some estimates suggest it is as high as 70%. Combining this information with the data in Figure 24.11A clearly shows the need to increase vaccination rates.

An interdisciplinary research team from the University of Minnesota (including expertise in public health, statistics, and philosophy) wondered if people in their state knew about herd immunity. Would learning about it impact their decision about whether to get the flu vaccine? For four days at a state fair in August 2016, the team asked the general public a variety of questions. Figure 24.11B shows a few questions from their survey, highlighting that the same question was asked before and after participants were given information about herd immunity.

The researchers found that most people surveyed, about 63%, were knowledgeable about herd immunity, selecting choice "a" from the first question in Figure 24.11B. Of those who were not knowledgeable, there was a 7.5% increase in those who planned to get vaccinated, a statistically significant increase.

The value of herd immunity. The results of this research demonstrate that educating people about herd immunity can impact their decision-making about vaccination. Yet changing someone's attitude is different from changing their behavior, and we don't know if people in this study followed through and actually got the vaccine. Until more people receive the flu vaccine, we're not likely to see a large change in the number of deaths caused by the influenza virus.

Currently, the flu is responsible for a lot of deaths, making the top 10 list of leading causes of death in the United States. In 2015, over 51,000 people died from influenza and its complications. To put that into perspective, in that same year, there were 80,000 deaths resulting from diabetes, and 40,000 people died from liver disease. Still, though, many people seem to think the flu is harmless!

The flu is the only leading cause of death that has an available vaccine, and yet year after year, low flu vaccination rates are a problem. As this study showed, a scientific approach can help us learn about public attitudes toward the flu vaccine and test solutions to improve the vaccination rate.

? How did the intervention for participants in the study (receiving knowledge about herd immunity) affect the rate of flu vaccinations in Minnesota in 2016?

What is herd immunity?
a) Vaccinating enough people to protect even those who are not vaccinated.
b) Vaccinating animals to protect humans from infection.
c) Vaccinating only those at high risk for disease.
d) Vaccinating adults and children several times within a year.
e) Vaccinating children who have already had the disease.

Participants were first asked what they know about herd immunity.

How likely are you to get the flu vaccine this year?
Extremely unlikely, Unlikely, Undecided, Likely, Extremely likely

Participants were then told the definition of herd immunity and given a short explanation about how it protects everyone, even those not vaccinated.

How likely are you to get the flu vaccine this year?
Extremely unlikely, Unlikely, Undecided, Likely, Extremely likely

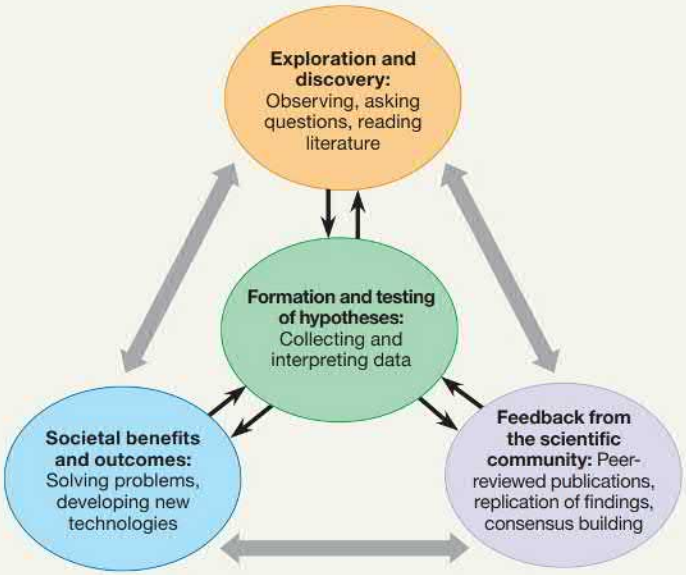
▲ Figure 24.11B A selection of survey questions from the study "What Have You Heard about the Herd?"

TRY THIS Try giving this set of survey questions to a few friends or family members, being sure to explain herd immunity to them, too.

Percentage vaccinated
100
50
0
2011–12
2013–14
2015–16
2017–18
Flu season

▲ Figure 24.11A Influenza vaccination rates for adults in the United States

500 CHAPTER 24 The Immune System



Presentation of the process of science in chapter 1 demonstrates to students the iterative nature of scientific research.

Visualize Tough Topics

Visualizing the Concept Modules bring dynamic visuals and text together to walk students through tough concepts. The ninth edition features 28 of these immersive modules. Select modules are assignable in Mastering Biology as animated videos.

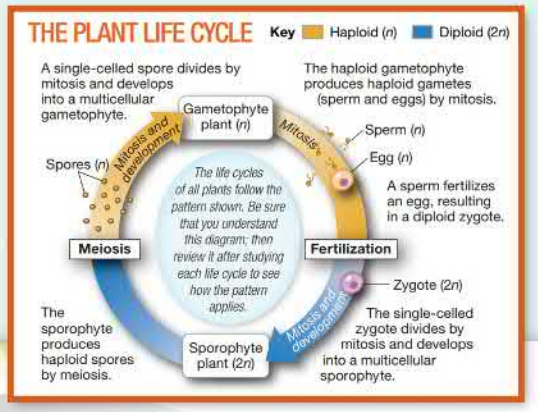
Embedded text **coaches students** through key points and **helps address common misunderstandings.**

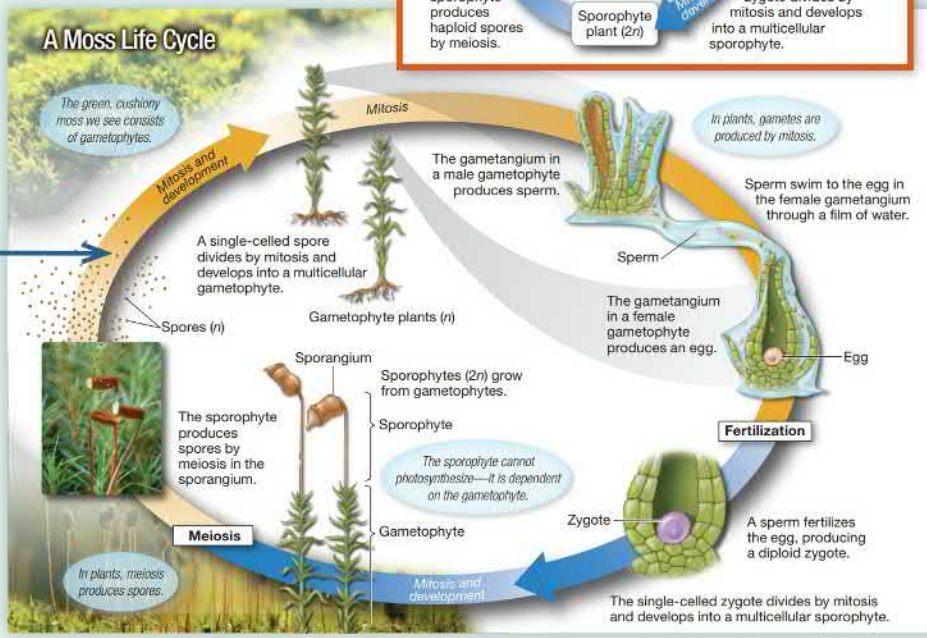
Alternation of Generations and Plant Life Cycles

VISUALIZING THE CONCEPT **17.3 Haploid and diploid generations alternate in plant life cycles**

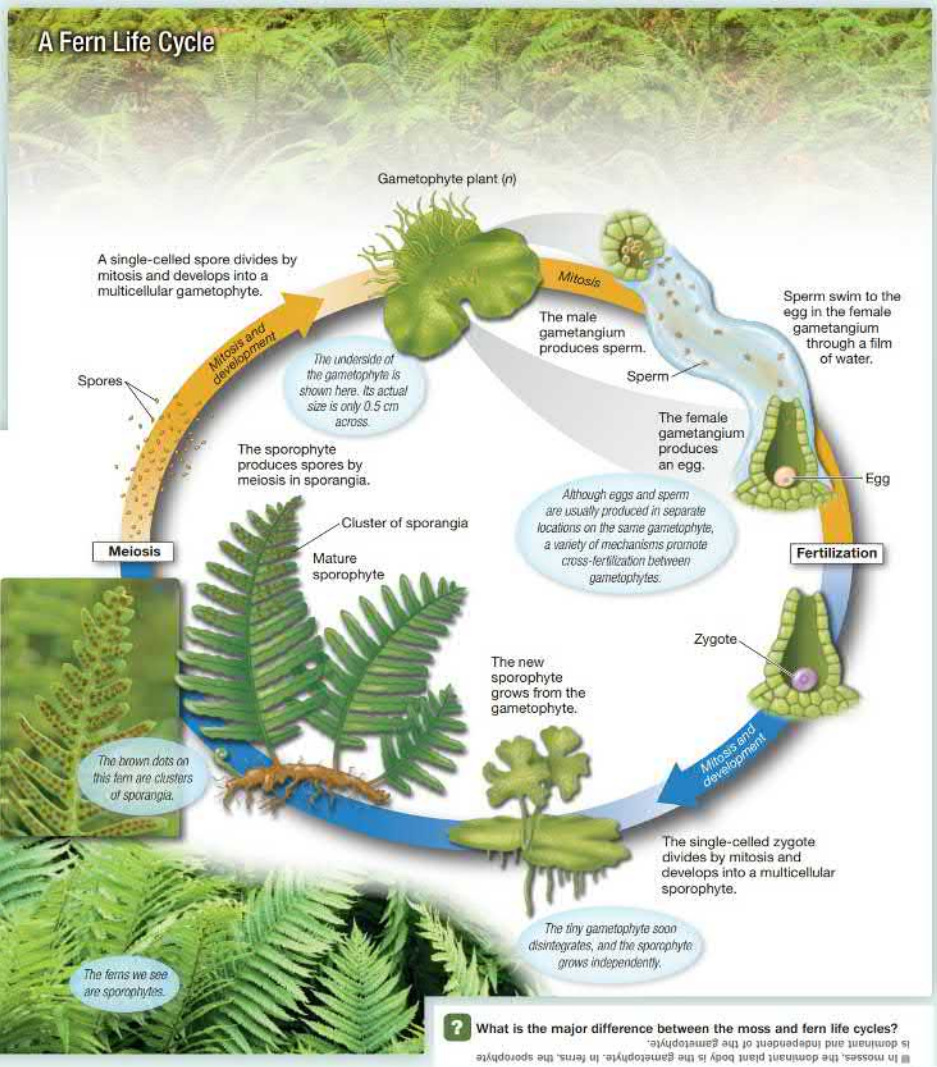
Plants have life cycles that are very different from ours. Humans are diploid individuals—that is, each of us has two sets of chromosomes, one from each parent (Module 8.12). Gametes (sperm and eggs) are the only haploid stage in the human life cycle. Plants have an **alternation of generations**: The diploid and haploid stages are distinct, multicellular bodies.

The haploid generation of a plant produces gametes and is called the **gametophyte**. The diploid generation produces spores and is called the **sporophyte**. In a plant's life cycle, these two generations alternate in producing each other. In mosses, as in all nonvascular plants, the gametophyte is the larger, more obvious stage of the life cycle. Ferns, like most plants, have a life cycle dominated by the sporophyte. Today, about 95% of all plants, including all seed plants, have a dominant sporophyte in their life cycle. The life cycles of all plants follow a pattern shown here. →





and Develop Understanding



? **What is the major difference between the moss and fern life cycles?**

In mosses, the dominant plant body is the gametophyte. In ferns, the sporophyte is dominant and independent of the gametophyte.

Streamlined text and illustrations **step students through the concept.**

Encourage Focus on

Main headings allow students to see the big picture.

A Central Concept at the start of each module helps students to focus on one concept at a time.

Gene Cloning and Editing

12.1 Genes can be cloned in recombinant plasmids

Although it may seem like a modern field, **biotechnology**, the manipulation of organisms or their components to make useful products, actually dates back to the dawn of civilization. Consider such ancient practices as the use of yeast to make beer and bread, and the selective breeding of livestock, dogs, and other animals. But when people use the term *biotechnology* today, they are usually referring to **DNA technology**, modern laboratory techniques for studying and manipulating genetic material. Using these methods, scientists can, for instance, extract genes from one organism and transfer them to another, effectively moving genes between species as different as *Escherichia coli* bacteria, papaya, and fish.

In the 1970s, the field of biotechnology was advanced by the invention of methods for making recombinant DNA in the lab. **Recombinant DNA** is formed when scientists combine pieces of DNA from two different sources—often different species—*in vitro* (in a test tube) to form a single DNA molecule. Today, recombinant DNA technology is widely used for **genetic engineering**, the direct manipulation of genes for practical purposes. Scientists have genetically engineered bacteria to mass-produce a variety of useful chemicals, from cancer drugs to pesticides. Scientists have also transferred genes from bacteria into plants and from one animal species into another (**Figure 12.1A**).

▲ **Figure 12.1A** Glowing aquarium fish (*Amatitlania nigrofasciatus*, a type of cichlid) produced by transferring a gene originally obtained from a jelly (cnidarian)

To manipulate genes in the laboratory, biologists often use bacterial **plasmids**, small, circular DNA molecules that replicate (duplicate) separately from the much larger bacterial chromosome (see Module 10.23). Plasmids typically carry only a few genes, can easily be transferred into bacteria, and are passed from one generation to the next. Because plasmids are easily manipulated to carry virtually any genes, they are key tools for **DNA cloning**, the production of many identical copies of a target segment of DNA. Through DNA cloning, scientists can mass produce many useful products.

Consider a typical genetic engineering challenge: A molecular biologist at a pharmaceutical company has identified a gene that codes for a valuable product, a hypothetical substance called protein V. The biologist wants to manufacture the protein on a large scale. The biggest challenge in such an effort is of the "needle in a haystack" variety: The gene of interest is one relatively tiny segment embedded in a much longer DNA molecule. **Figure 12.1B** illustrates how the techniques of gene cloning can be used to mass produce a desired gene.

To begin, the biologist isolates two kinds of DNA: (1) a bacterial plasmid (usually from the bacterium *E. coli*) that will serve as the **vector**, or gene carrier, and (2) the DNA from another organism ("foreign" DNA) that includes the gene that codes for protein V (gene *V*) along with other, unwanted genes. The DNA containing gene *V* could come from a variety of sources, such as a different bacterium, a plant, a nonhuman animal, or even human tissue cells growing in laboratory culture.

(3) The researcher treats both the plasmid and the gene *V* source DNA with an enzyme that cuts DNA. An enzyme is chosen that cleaves the plasmid in only one place. (4) The source DNA, which is usually much longer in sequence than the plasmid, may be cut into many fragments, only one of which carries gene *V*. The figure shows the processing of just one DNA fragment and one plasmid, but actually, millions of plasmids and DNA fragments, most of which do not contain gene *V*, are treated simultaneously.

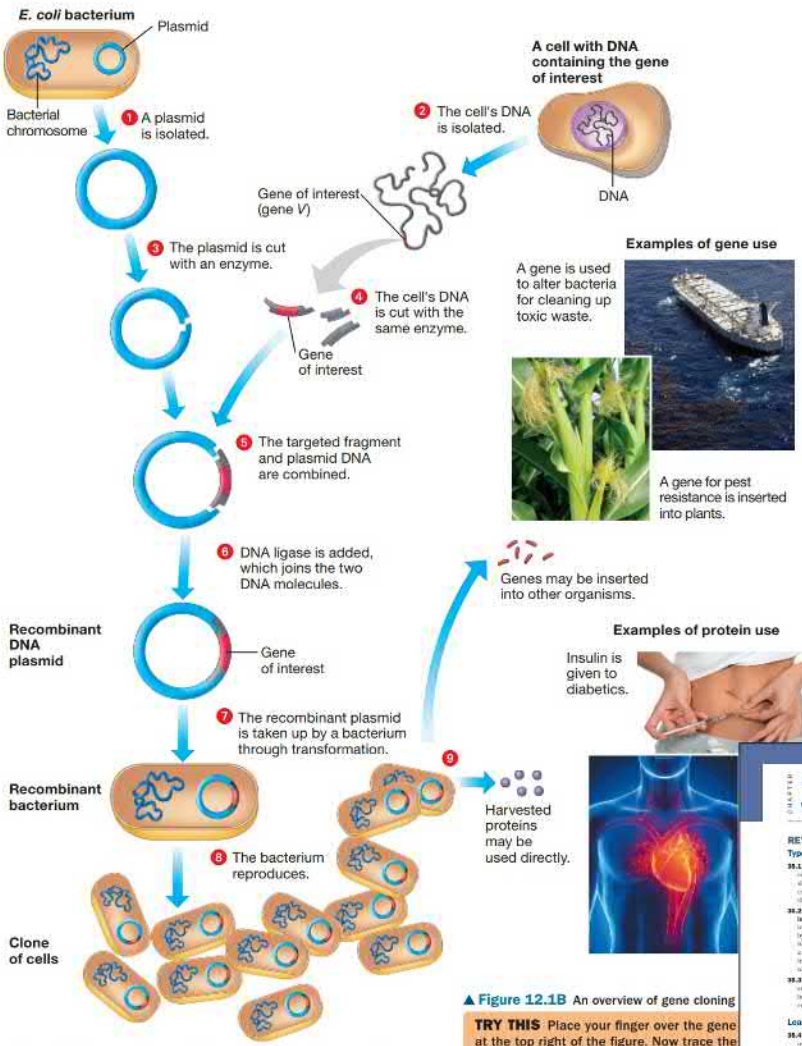
(5) The cut DNA from both sources—the plasmid and target gene—are mixed. The single-stranded ends of the plasmid base-pair with the complementary ends of the target DNA fragment (see Module 10.3 if you need a refresher on the DNA base-pairing rules). (6) The enzyme **DNA ligase** joins the two DNA molecules by way of covalent bonds. This enzyme, which the cell normally uses in DNA replication (see Module 10.4), is a "DNA pasting" enzyme that catalyzes the formation of covalent bonds between adjacent nucleotides, joining the strands. The resulting plasmid is a recombinant DNA molecule.

(7) The recombinant plasmid containing the targeted gene is mixed with bacteria. Under the right conditions, a bacterium takes up the plasmid DNA by transformation (see Module 10.22). (8) The recombinant bacterium then reproduces through repeated cell cycles to form a **clone** of cells, a population of genetically identical cells. In this clone, each bacterium carries a copy of gene *V*. When DNA cloning involves a gene-carrying segment of DNA (as it does here), it is called **gene cloning**. In our example, the biologist will eventually grow a cell clone large enough to produce protein *V* in marketable quantities.

(9) Gene cloning can be used for two basic purposes. Copies of the gene itself can be the immediate product, to be used in additional genetic engineering projects. For example, a pest-resistance gene present in one plant species might be cloned and transferred into plants of another species. Other times, the protein product of the cloned gene is harvested

Figures describing a process take students through a series of numbered steps keyed to explanations in the text.

Key Concepts and Active Learning



▲ **Figure 12.1B** An overview of gene cloning

TRY THIS Place your finger over the gene at the top right of the figure. Now trace the throughout the entire process shown.

? In the example shown in Figure 12.1B

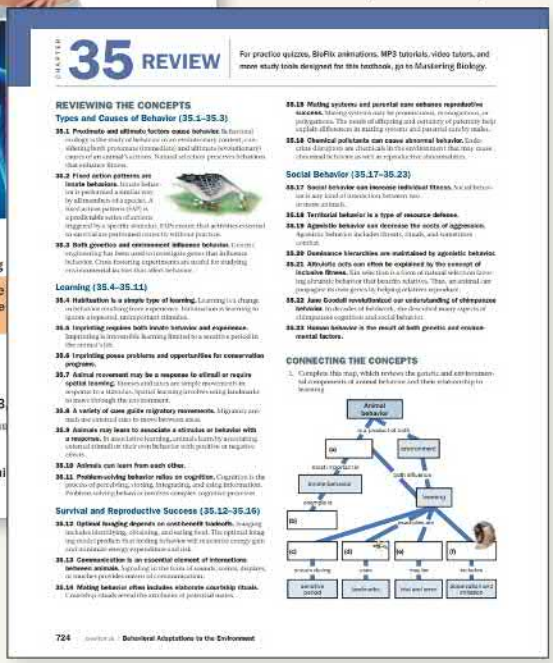
Gene Cloni

and used. For example, a protein with medical uses, such as insulin, can be harvested in large quantities using recombinant bacteria.

In the next four modules, we discuss the methods outlined in Figure 12.1B. You may find it useful to turn back to this summary figure as each technique is discussed.

Checkpoint questions at the end of every module let students check their understanding right away.

Chapter summaries include figures and text to help students review and check their understanding of the chapter concepts.



CHAPTER **35** REVIEW

For practice quizzes, BioFlix animations, MP3 tutorials, video tutors, and more study tools designed for this textbook, go to Mastering Biology.

REVIEWING THE CONCEPTS

Types and Causes of Behavior (35.1–35.3)

Learning (35.4–35.11)

Survival and Reproductive Success (35.12–35.16)

Social Behavior (35.17–35.23)

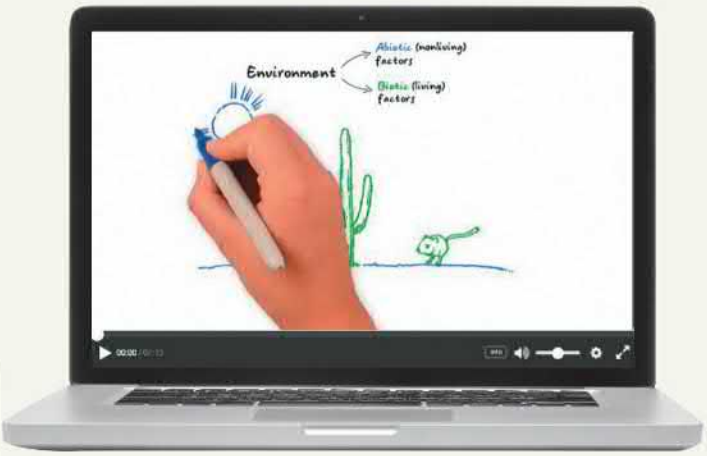
CONNECTING THE CONCEPTS

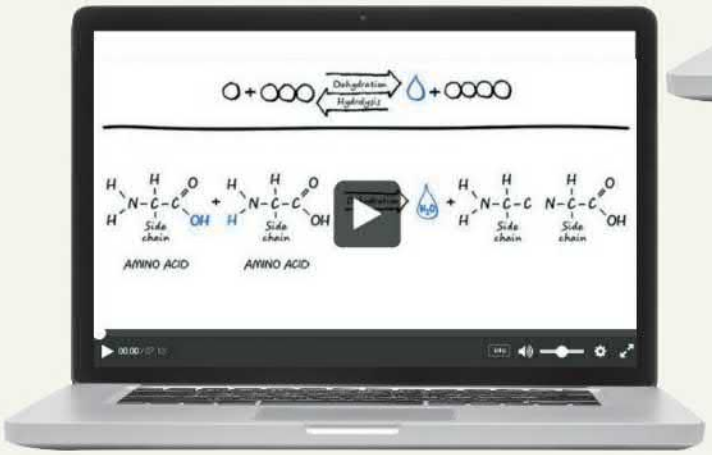
724

Try This activities in every chapter encourage students to actively engage with the figures and develop positive study habits.

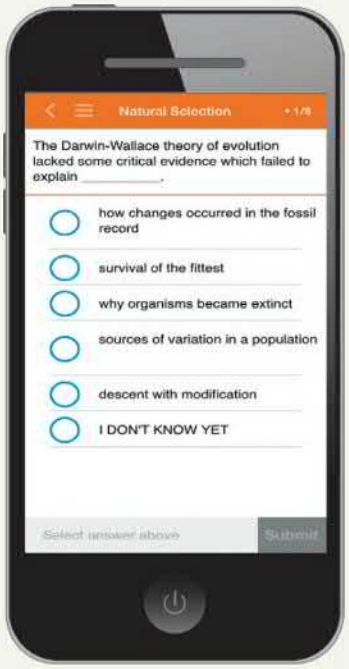
Dynamic Digital Resources

Key Topic Overview videos introduce students to key concepts and vocabulary and are created by authors Eric Simon, Jean Dickey and Kelly Hogan. All 12 videos are delivered as a whiteboard style mini-lesson and are accompanied by assessment so that students can check their understanding.

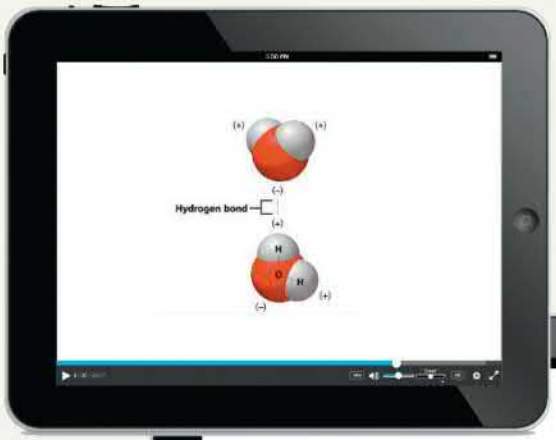


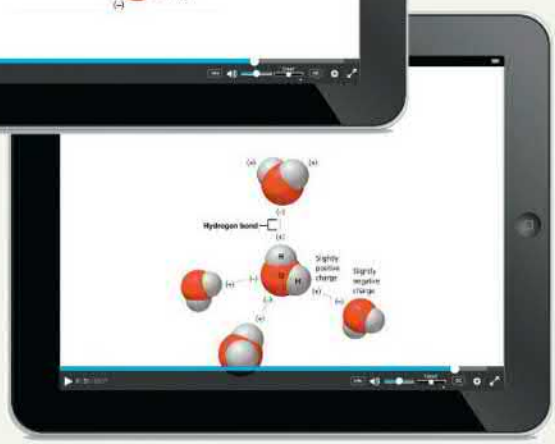


Dynamic Study Modules provide students with multiple sets of questions with extensive feedback so that they can test, learn, and retest until they achieve mastery of the textbook material.



Bring Biology to Life





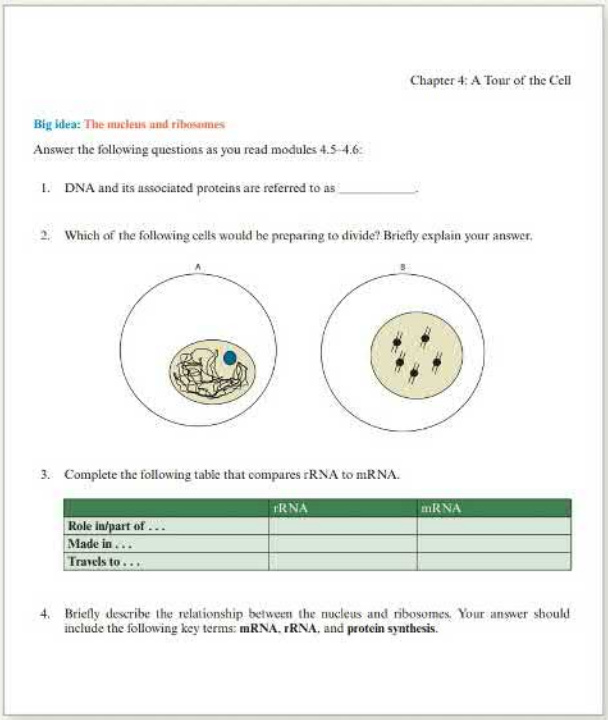
NEW! Figure Walkthroughs videos guide students through key figures with narrated explanations, figure markups, and questions that reinforce important points. Questions embedded in each Figure Walkthrough encourage students to be active participants in their learning.

Give students extra practice with **assignable Visualizing the Concept videos**, which pair with the select modules in the text.

Everything Students and Instructors

HHMI Short Films are documentary-quality movies from the Howard Hughes Medical Institute with explorations from the discovery of the double helix to evolution and include assignable questions.

UPDATED Active Reading Guides are designed to aid students in getting the most out of their reading and are aimed at moving them from passive learning to active learning. Active Reading Guides accompany every chapter and are available for students to download and complete in the Mastering Study Area.



Chapter 4: A Tour of the Cell

Big idea: The nucleus and ribosomes

Answer the following questions as you read modules 4.5–4.6:

1. DNA and its associated proteins are referred to as _____.

2. Which of the following cells would be preparing to divide? Briefly explain your answer.

A B

3. Complete the following table that compares rRNA to mRNA.

	rRNA	mRNA
Role in/part of . . .		
Made in . . .		
Travels to . . .		

4. Briefly describe the relationship between the nucleus and ribosomes. Your answer should include the following key terms: **mRNA**, **rRNA**, and **protein synthesis**.

Resources to help instructors plan dynamic lectures:

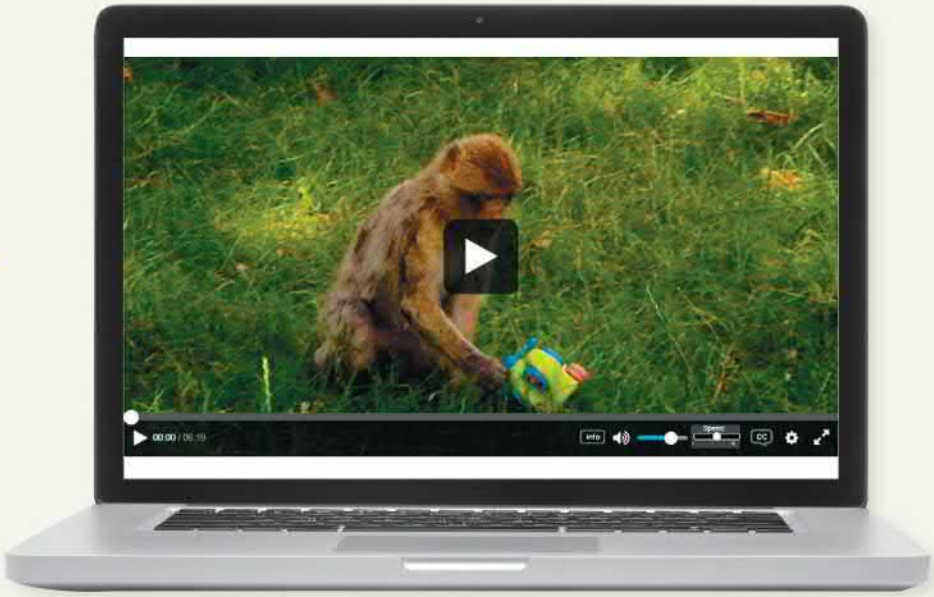
- **Ready-to-Go Teaching Modules** help instructors efficiently make use of the available teaching tools for the toughest topics.
- The **Instructor Exchange** provides active learning techniques from biology instructors around the nation. Co-author Kelly Hogan moderates the exchange.

Need to Succeed in Mastering Biology

Learning Catalytics is a "bring your own device" (laptop, smartphone, or tablet) engagement, assessment, and classroom intelligence system that allows for active learning and discussion.

Try This questions in Learning Catalytics are easy to assign in-class active learning questions, based on the text "Try This" feature.

Everyday Biology Videos briefly explore interesting and relevant biology topics that relate to concepts that students are learning in class. These 20 videos, produced by the BBC, can be assigned in Mastering Biology.

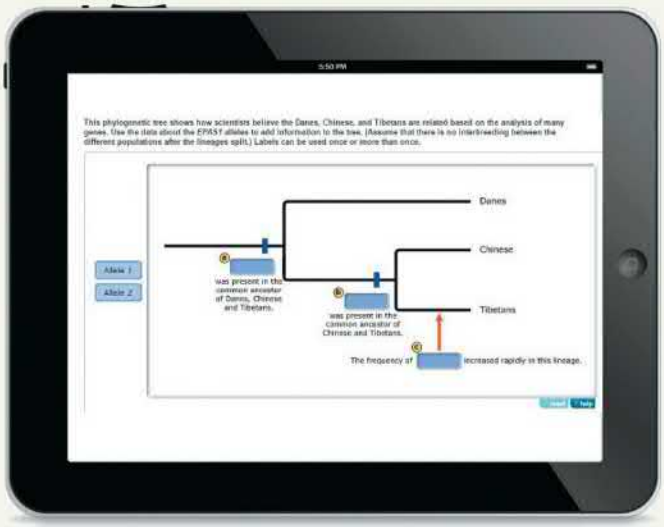


Engage in Biology Anytime, Anywhere

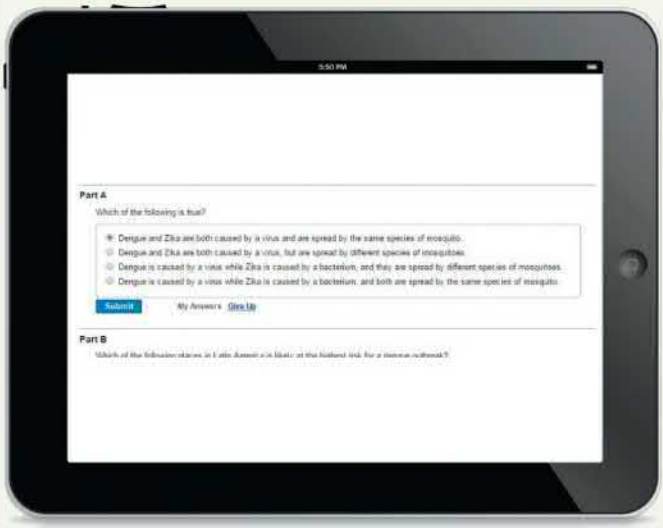
Scientific Thinking Activities help students develop an understanding of how scientific research is conducted.

Examples of topics include:

- What Is the Role of Peer Review in the Process of Science?
- How Does "Citizen Science" Affect Scientific Data Collection?
- Do the Microorganisms in Our Digestive Tract Play a Role in Obesity?



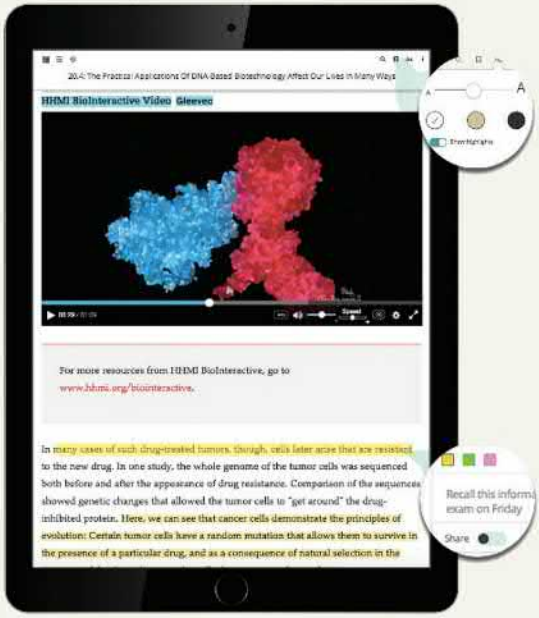
Current Events Activities cover a wide range of biological topics to demonstrate to students how science connects to everyday life.



with Mastering Biology

Evaluating Science in the Media Activities teach students to recognize validity, bias, purpose, and authority in everyday sources of information.

NEW Pearson eText is a simple-to-use, mobile-optimized, personalized reading experience available within Mastering. It allows students to easily highlight, take notes, and review key vocabulary all in one place—even when offline. Seamlessly integrated videos and other rich media engage students and give them access to the help they need, when they need it.



Preface

Inspired by the thousands of students in our own classes over the years and by enthusiastic feedback from the many instructors who have used or reviewed our book, we are delighted to present this new, Tenth Edition. We authors have worked together closely to ensure that both the book and the supplementary material online reflect the changing needs of today's courses and students, as well as current progress in biology. Titled *Campbell Biology: Concepts & Connections* to honor Neil Campbell's founding role and his many contributions to biology education, this book continues to have a dual purpose: to engage students from a wide variety of majors in the wonders of the living world and to show them how biology relates to their own existence and the world they inhabit. Most of these students will not become biologists themselves, but their lives will be touched by biology every day. Understanding the concepts of biology and their connections to our lives is more important than ever. Whether we're concerned with our own health or the health of our planet, a familiarity with biology is essential. This basic knowledge and an appreciation for how science works have become elements of good citizenship in an era when informed evaluations of health issues, environmental problems, and applications of new technology are critical.

Concepts and Connections

Concepts Biology is a vast subject that gets bigger every year, but an introductory biology course is still only one or two semesters long. This book was the first introductory biology textbook to use concept modules to help students recognize and focus on the main ideas of each chapter. The heading of each module is a carefully crafted statement of a key concept. For example, "Helper T cells stimulate the humoral and cell-mediated immune responses" announces a key concept about the role of helper T cells in adaptive immunity (Module 24.12). Such a concept heading serves as a focal point, and the module's text and illustrations converge on that concept with explanation and, often, analogies. The module text walks the student through the illustrations, just as an instructor might do in class. And in teaching a sequential process, such as the one diagrammed in Figure 24.12A, we number the steps in the text to correspond to numbered steps in the figure. The synergy between a module's narrative and graphic components transforms the concept heading into an idea with meaning to the student. The checkpoint question at the end of each module encourages students to test their understanding as they proceed through a chapter. Finally, in the Chapter Review, all the key concept statements are listed and briefly summarized under the overarching section titles, explicitly reminding students of what they've learned.

Connections Students are more motivated to study biology when they can connect it to their own lives and interests—for example, when they are able to relate science to health issues, economic problems, environmental quality, ethical controversies, and social responsibility. In this edition, purple Connection icons mark the numerous application modules that go beyond the core biological concepts. For example, Connection Module 32.6 describes how humans tap into plant transport mechanisms for harvesting such materials as maple syrup and latex. In addition, our Evolution Connection modules, identified by green icons, connect the content of each chapter to the grand unifying theme of evolution, without which the study of life has no coherence. For example, the Evolution Connection in Chapter 14 uses data from studies by Rosemary and Peter Grant and their students to demonstrate the continuing effects of natural selection on Darwin's finches. Explicit connections are also made between the chapter introduction and either the Evolution Connection module or the Scientific Thinking module in each chapter. And, connections are made in every chapter between key concepts and the core concepts of biology.

In This Edition

NEW! Chapter Openers Re-envisioned We have redesigned the opening of every chapter of the text, based on our own data analytics and feedback from students and instructors. The result is more visual, more interactive, and more engaging. The opening narrative has been shortened, the Big Ideas covered in the chapter are clearly described, and pre-test questions help students prepare themselves for the new content. Additionally, all chapter-opening essays are now assigned a module number, making them easier to assign and assess.

Focus on Five Underlying Themes of Biology
A major goal of this Tenth Edition is to provide students with an explicit framework for understanding and organizing the broad expanse of biological information presented in Concepts and Connections. This framework is based on the five major themes outlined in *Vision and Change in Undergraduate Biology Education: A Call to Action* published by the American Academy for the Advancement of Science. These major themes extend across all areas of biology: evolution, the flow of information, the correlation of structure and function, the exchange of energy and matter, and the interactions and interconnections of biological systems. Chapter 1 introduces each of these themes in a separate module. Specific examples of the themes are then called out in each chapter by green icons: INFORMATION, STRUCTURE AND FUNCTION, ENERGY AND MATTER, INTERACTIONS, and EVOLUTION CONNECTION (always in module form).

Expanded Coverage of the Process of Science
Chapter 1 also includes an enhanced focus on the nature of science and the process of scientific inquiry, setting the stage for both the content of the text and the process by which our biological knowledge has been built and continues to grow. We continue this emphasis on the process of scientific inquiry through our Scientific Thinking modules in every chapter, which are called out with an orange icon. The concept check questions for these modules focus on aspects of the process of science: the forming and testing of hypotheses; experimental design; variables and controls; the analysis of data; and the evaluation and communication of scientific results.

Visualizing the Concept Modules These modules, which were new to the Eighth Edition, have raised our hallmark art–text integration to a new level. Visualizing the Concept modules take challenging concepts or processes and walk students through them in a highly visual manner, using engaging, attractive art; clear and concise labels; and instructor "hints" called out in light blue bubbles. These short hints emulate the one-on-one coaching an instructor might provide to a student during office hours and help students make key connections within the figure. Examples of Visualizing the Concept modules include Module 6.11, Most ATP production occurs by oxidative phosphorylation; Module 8.17, Crossing over further increases genetic variability; Module 13.14, Natural selection can alter variation in a population in three ways; Module 28.6, Neurons communicate at synapses, and Module 34.18, The global water cycle connects aquatic and terrestrial biomes.

Visualizing the Data Figures First introduced in the Ninth Edition, these figures present data in an infographic form, marked by Visualizing the Data icons.

These 19 eye-catching figures provide students with a fresh approach to understanding the concepts illustrated by graphs and numerical data. Figure 10.19 maps emergent virus outbreaks, showing that they originate throughout the world. Figure 12.17 summarizes a wealth of bioinformatics data on genome sizes versus the number of genes found in various species. Figure 13.16 illustrates the growing threat of antibiotic resistant bacteria. Figure 21.14 allows students to directly compare caloric intake (via food) with caloric expenditure (via exercise). Figure 30.5B shows changes in bone mass during the human life span. Figure 36.11 offers an illuminating visual comparison of the per capita and national ecological footprints of several countries with world average and "fair share" footprints. Figure 38.3 shows graphic evidence of global warming by tracking annual global temperatures since 1880.

Unit Openers That Feature Careers Related to the Content of the Unit Expanding our emphasis on the connections of biology to students' lives, each unit opener page now includes photos of individuals whose professions relate to the content of the unit. For instance, Unit I features a brewery owner and a solar energy engineer. Unit IV portrays a hatchery manager and a paleoanthropologist. These examples are intended to help students see how their biology course relates to the world outside the classroom and to their own career paths.

The Latest Science Biology is a dynamic field of study, and we take pride in our book's currency and scientific accuracy. For this edition, as in previous editions, we have integrated the results of the latest scientific research throughout the book. We have done this carefully and thoughtfully, recognizing that research advances can lead to new ways of looking at biological topics; such changes in perspective can necessitate organizational changes in our textbook to better reflect the current state of a field. For example, Chapter 12 uses both text and art to present the innovative CRISPR-Cas9 system for gene editing. You will find a unit-by-unit account of new content and organizational improvements in the "New Content" section on pages xix–xx following this Preface.

Mastering Biology Mastering Biology, the most widely used online tutorial and assessment program for biology, continues to accompany *Campbell Biology: Concepts & Connections*. In addition to 170 author-created activities that help students learn vocabulary, extend the book's emphasis on visual learning, demonstrate the connections among key concepts (helping students grasp the big ideas), and coach students on how to interpret data, the Tenth Edition features assignable videos. These videos bring this text's Visualizing the Concept modules to life, help students learn how to evaluate sources of scientific information for reliability, and include short news videos that engage students in the many ways course concepts connect to the world outside the classroom. Mastering Biology for *Campbell Biology: Concepts & Connections*, Tenth Edition, will help students to see strong connections through their text, and the additional practice available online allows instructors to capture powerful data on student performance, thereby making the most of class time.

This Book's Flexibility

Although a biology textbook's table of contents is by design linear, biology itself is more like a web of related concepts without a single starting point or prescribed path. Courses can navigate this network by starting with molecules, with ecology, or somewhere in-between, and courses can omit topics. *Campbell Biology: Concepts & Connections* is uniquely suited to offer flexibility and thus serve a variety of courses. The seven units of the book are largely self-contained, and in a number of the units, chapters can be assigned in a different order without much loss of coherence. The use of numbered modules makes it easy to skip topics or reorder the presentation of material.

For many students, introductory biology is the only science course that they will take during their college years. Long after today's students have forgotten most of the specific content of their biology course, they will be left with general impressions and attitudes about science and scientists. We hope that this new edition of *Campbell Biology: Concepts & Connections* helps make those impressions positive and supports instructors' goals for sharing the fun of biology. In our continuing efforts to improve the book and its supporting materials, we benefit tremendously from instructor and student feedback, not only in formal reviews but also via informal communication. Please let us know how we are doing and how we can improve the next edition of the book.

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Organization and New Content

Below are some important highlights of recent updates and organizational improvements in *Campbell Biology: Concepts & Connections*, Tenth Edition.

Chapter 1, Biology: Exploring Life Our expanded coverage of the nature of science and scientific inquiry has moved to the forefront of Chapter 1. The first of the five modules in this section provides a general description of data, hypothesis formation and testing, the centrality of verifiable evidence to science, and an explanation of scientific theories. The module describing how hypotheses can be tested using controlled experiments includes a subsection on hypothesis testing in humans. The Scientific Thinking module entitled Hypotheses can be tested using observational data, describes how multiple lines of evidence, including DNA comparisons, have helped resolve the classification of the red panda. The process of science is repetitive, nonlinear, and collaborative module presents a more accurate model of the process of science that includes four interacting circles: Exploration and Discovery; Forming and Testing Hypotheses: Analysis and Feedback from the Scientific Community; and Societal Benefits and Outcomes. The chapter concludes with the introduction of five core themes that underlie all of biology: evolution; information; structure and function; energy and matter; and interactions.

Unit I, The Life of the Cell This unit guides students from basic chemistry and the molecules of life through cellular structures to cellular respiration and photosynthesis. Throughout the Tenth Edition, the five themes introduced in Chapter 1 are highlighted with specific references. Examples from Unit 1 include "Illustrating our theme of ENERGY AND MATTER, we see that matter has been rearranged, with an input of energy provided by sunlight" (Module 2.9); "The flow of genetic instruction that leads to gene expression, summarized as DNA → RNA → protein, illustrates the important biological theme of INFORMATION" (Module 3.15); "The interconnections among these pathways provide a clear example of the theme of INTERACTIONS in producing the emergent property of a balanced metabolism" (Module 6.15); and "The precise arrangements of these membranes and compartments are essential to the process of photosynthesis—a classic example of the theme of STRUCTURE AND FUNCTION" (Module 7.2). The theme of evolution is featured, as it is in every chapter, in an Evolution Connection module, such as Module 4.15, Mitochondria and chloroplasts evolved by endosymbiosis. Two Visualizing the Concept modules are Module 2.6, Covalent bonds join atoms into molecules through electron sharing, and Module 6.9, Most ATP production occurs by oxidative phosphorylation. Both use art to guide students through these challenging topics. Connection Modules emphasize the process of science and societal interactions such as Module 3.6, Are we eating too much sugar? (which includes a Visualizing the Data figure on recommended and actual sugar consumption), and Module 7.14, Reducing both fossil fuel use and deforestation may moderate climate change (which includes updated information on the 2015 Paris climate accord). Orientation diagrams help students follow the various stages of cellular respiration and photosynthesis in Chapters 6 and 7. In Chapter 6, a new organization of the modules describing the three stages of cellular respiration allows more flexibility in reading and assigning either just the overview or both the overview plus in-depth coverage. Chapter 7 opens with a new topic on harnessing biofuels in Module 7.0 Sunlight can provide renewable energy for our cars.

Unit II, Cellular Reproduction and Genetics The purpose of this unit is to help students understand the relationship between DNA, chromosomes, and organisms and to help students see that genetics is not purely hypothetical but connects in many important and interesting ways to their lives, human society, and other life on Earth. The content has been reinforced with discussions of relevant topics, such as DCIS (also called stage 0 breast cancer), increased use of genetically modified organisms (GMOs), recent examples of DNA profiling, information about the 2015 California measles outbreak, a new infographic that charts emergent virus outbreaks, and new data on the health prospects of clones. This edition includes discussion of many recent advances in the field, such as an updated definition of the gene, and a largely new presentation of DNA technologies and bioinformatics, including extensive discussion in both text and art of the CRISPR-Cas9 system, GenBank, and BLAST searches. In some cases, sections within chapters have been reorganized to present a more logical flow of materials. Examples include an improved presentation of the genetics underlying cancer, a Visualizing the Concept module on crossing over, a circular genetic code chart that should improve student understanding, and a Visualizing the Data that summarizes relevant information about different types of cancer and their survival rates. Material throughout the unit has been updated to reflect recent data, such as the latest statistics on cancer, cystic fibrosis, and Down syndrome, an improved model of ribosomes, new information about prions, expanded coverage of noncoding small RNAs, new human gene therapy trials, recent information about Y chromosome inheritance, and what information home tests can reveal about your genetic heritage.

Unit III, Concepts of Evolution This unit presents the basic principles of evolution and natural selection, the overwhelming evidence that supports these theories, and their relevance to all of biology—and to the lives of students. For example, a Visualizing the Data figure (13.16) illustrates

the growing threat of antibiotic resistance. Chapter 13 also includes a Visualizing the Concept module (13.14) on the effects of natural selection that shows experimental data along with hypothetical examples. Chapter 14 contains an Evolution Connection module (14.9) featuring the work of Rosemary and Peter Grant on Darwin's finches. Modules 15.14 to 15.19 were revised to improve the flow and clarity of the material on phylogenetics and include updates from genomic studies and new art (for example, Figures 15.17 and 15.19A).

Unit IV, The Evolution of Biological Diversity The diversity unit surveys all life on Earth in less than a hundred pages! Consequently, descriptions and illustrations of the unifying characteristics of each major group of organisms, along with a small sample of its diversity, make up the bulk of the content. Two recurring elements are interwoven with these descriptions: evolutionary history and examples of relevance to our everyday lives and society at large. With the rapid accumulation of molecular evidence, taxonomic revisions are inevitable. These changes are reflected in Chapter 16, Microbial Life, with a module and figure (16.13) on protist supergroups, and in Chapters 18 and 19, Evolution of Invertebrate Diversity and Evolution of Vertebrate Diversity, with three modules about animal phylogeny (18.10, 18.11, and 19.1). The importance of metagenomics to the study of microorganisms is highlighted in Modules 16.1 and 16.7 (prokaryotes) and 17.14 (fungi). Examples of relevance include valley fever, a fungal disease linked to climate change (Module 17.19), and a Visualizing the Data figure (19.16) on the evolution of human skin color.

Unit V, Animals: Form and Function This unit combines a comparative animal approach with an exploration of human anatomy and physiology. Chapter 20, Unifying Concepts of Animal Structure and Function, opens with Module 20.0 Evolution does not produce perfection, and the Evolution Connection, Module 20.1 follows with a discussion of the lengthy laryngeal nerve in giraffes. By illustrating that a structure in an ancestral organism can become adapted to function in a descendant organism without being "perfected," this example helps to combat a common student misconception about evolution. The main portion of every chapter in this unit is devoted to detailed presentations of human body systems, frequently illuminated by discussion of the health consequences of disorders in those systems. The Chapter 22 opener (22.0) and Scientific Thinking module (22.7) compare the conclusions from long term studies on the health hazards of cigarette smoking with the very recent research on the effects of e-cigarettes. In Chapter 23, Circulation, the Scientific Thinking module (23.6) discusses the consequences of treating coronary artery disease with medicine or both medicine and stents. Chapter 29, The Senses, incorporates material on common eye conditions, glaucoma and cataracts. Visualizing the Concept modules on osmoregulation (25.4) and neuronal synapses (28.6) help students better envision big concepts. Visualizing the Data figures detail data on hypertension in the United States (23.9B), worldwide HIV infection and treatments (24.14B), and changes in bone mass during the human life span (30.5B). Chapter 21, Nutrition and Digestion, includes a discussion of human microbiome and microbiota presents the latest FDA requirements for food nutritional labels. Module 22.9, Breathing is automatically controlled, uses an equation showing the formation and dissociation of carbonic acid that accompanies the discussion of how the medulla regulates breathing and illustrates that process in Figure 22.9. In Chapter 24, a new Scientific Inquiry (Module 24.11 Why is herd immunity so difficult with the flu?) provides more resources for educators who want to discuss vaccination. Another new Scientific Inquiry module examines thermal image data around a mosquito feeding on warm blood (25.3). Updates in Chapter 28 reflect the current understanding about the numbers of neurons in humans (28.15) and help correct misconceptions for student about sleep (28.19).

Unit VI, Plants: Form and Function To help students gain an appreciation of the importance of plants, this unit presents the anatomy and physiology of angiosperms with frequent connections to the importance of plants to society. Connections modules include an improved discussion of agriculture via artificial selection on plant parts and via plant cloning in Chapter 31; discussions of organic farming, human harvesting of plant transport products (such as maple syrup and rubber), and GMOs in Chapter 32; and a discussion of caffeine as an evolutionary adaptation that can prevent herbivory in Chapter 33. The discussion of plant nutrients is presented as a large Visualizing the Data in Module 32.7, and the presentation of the potentially confusing topic of the effect of auxin on plant cell elongation also benefits from a visual presentation (Figure 33.3B). All of these examples are meant to make the point that human society is inexorably connected to the health of plants.

Unit VII, Ecology In this unit, students learn the fundamental principles of ecology and how these principles apply to environmental problems. The Tenth Edition features a Visualizing the Concept module that explains the global water cycle (34.18) and Visualizing the Data figures that compare ecological footprints (36.11), track global temperatures since 1880 (38.3A), and illustrate the results of a study on optimal foraging theory (35.12). The new focus of Module 35.0 is on the topic of how altruism can evolve. Module 35.16 has examples of the effects of endocrine-disrupting chemicals on animal behavior and the EPA's progress in evaluating endocrine disruptors in pesticides as potential hazards to human health. Other content updates in this unit include human population data (36.9 and 36.10) and species at risk for extinction (38.1). The unit-wide emphasis on climate change and sustainability continues in this edition with updates to the module on ecological footprints (36.11), rapid warming (38.3), rising concentrations of greenhouse gases (38.4) and the catastrophic 2018 fire season (38.5). The Scientific Thinking Module 38.11 has been revised to include the presentation of a study with data, making the module more focused on science skills.

Acknowledgments

This Tenth Edition of *Campbell Biology: Concepts & Connections* is a result of the combined efforts of many talented and hardworking people, and the authors wish to extend heartfelt thanks to all those who contributed to this and previous editions. Our work on this edition was shaped by input from the biologists acknowledged in the reviewer list on pages xxii–xxiv, who shared with us their experiences teaching introductory biology and provided specific suggestions for improving the book. Feedback from the authors of this edition's supplements and the unsolicited comments and suggestions we received from many biologists and biology students were also extremely helpful. In addition, this book has benefited in countless ways from the stimulating contacts we have had with the coauthors of *Campbell Biology*, Eleventh Edition.

We wish to offer special thanks to the students and faculty at our teaching institutions. Marty Taylor thanks her students at Cornell University for their valuable feedback on the book. Eric Simon thanks his colleagues and friends at New England College, especially within the Division of Natural and Social Sciences, for their continued support and assistance. Jean Dickey thanks her colleagues at Clemson University for their expertise and support. And Kelly Hogan thanks her students for their enthusiasm and colleagues at the University of North Carolina, Chapel Hill, for their continued support.

This edition benefited significantly from the efforts of contributor Rebecca S. Burton from Alverno College. Using her years of teaching expertise, Becky made substantial improvements to her two chapters. We thank Becky for bringing her considerable talents to this edition.

The superb publishing team for this edition was headed up by content strategy manager Josh Frost and content strategy director Jeanne Zalesky. We cannot thank them enough for their unstinting efforts on behalf of the book and for their commitment to excellence in biology education. We are fortunate to have had once again the contributions of content development director Ginnie Simione Jutson. We are similarly grateful to the members of the editorial development team—Evelyn Dahlgren, Alice Fugate and Mary Catherine Hager—for their steadfast commitment to quality. We thank them for their thoroughness, hard work, and good humor; the book is far better than it would have been without their efforts. Thanks also to supplements project editor Melissa O'Conner on her oversight of the supplements program and to the efficient and enthusiastic support she provided.

This book and all the other components of the teaching package are both attractive and pedagogically effective in large part because of the hard work and creativity of the production professionals on our team. We wish to thank managing producer Mike Early and content producer Laura Perry. We also acknowledge copy editor Joanna Dinsmore, proofreader Gina Mushynsky, and indexer Razorsharp Communications, Inc. We again thank photo researcher Kristin Piljay for her contributions, as well as rights and permissions manager Matt Perry. Integra was responsible for composition, headed by production project manager Marianne Peters-Riordan, and the art house Lachina, headed by project manager Rebecca Marshall, who was responsible for overseeing the rendering of new and revised illustrations. We also thank manufacturing overseer Stacey Weinberger.

We thank Elise Lansdon for creating a beautiful and functional interior design and a stunning cover, and we are again indebted to design manager Mark Ong for his oversight and design leadership.

The value of *Campbell Biology: Concepts & Connections* as a learning tool is greatly enhanced by the hard work and creativity of the authors of the supplements that accompany this book: Ed Zalisko (*Instructor's Guide* and *PowerPoint® Lecture Presentations*); Jean DeSaix, Kristen Miller, Justin Shaffer, and Suann Yang (*Test Bank*); Dana Kurpius (*Active Reading Guide*); Bob Iwan (*Reading Quizzes*); Cheri LaRue (media correlator), and Brenda Hunzinger (*Clicker Questions* and *Quiz Shows*). In addition to supplements project editor Melissa O'Conner, the editorial and production staff for the supplements program included supplements production project manager Alverne Ball (Integra), Marsha Hall (PPS), and Jennifer Hastings (PPS). And the superlative Mastering Biology program for this book would not exist without Lauren Fogel, Stacy Treco, Katie Foley, Sarah Jensen, Chloé Veylit, Jim Hufford, Charles Hall, Caroline Power, and David Kokorowski and his team. And a special thanks to Arl Nadel and Sarah Young-Dualan for their thoughtful work on the Visualizing the Concepts interactive videos.

For their important roles in marketing the book, we are very grateful to marketing manager Christa Pelaez and vice president of marketing Christy Lesko. The members of the Pearson Science sales team have continued to help us connect with biology instructors and their teaching needs, and we thank them.

Finally, we are deeply grateful to our families and friends for their support, encouragement, and patience throughout this project. Our special thanks to Josie, Jason, Marnie, Alice, Jack, David, Paul, Ava, and Daniel (M.R.T.); Amanda, Reed, Forest, and my inspirations M.K., J.K., M.S., and J.J. (E.J.S.); Jessie and Katherine (J.L.D.); and Tracey, Vivian, Carolyn, Brian, Jake, and Lexi (K.H.)

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